Monsoon Disturbances Over Southeast and East Asia and the Adjacent Seas

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LONG TERM GOALS

To study weather disturbances over the Southeast and East Asian monsoon region and its adjacent seas using Navy research and operational analysis and forecast models. The primary goal is to advance our understanding of the weather-producing systems in the region, in order to improve forecast capabilities. In the process we will assess the skill and characteristics of the models in representing and forecasting these disturbances and find clues that may be useful for model improvement efforts.

OBJECTIVES

The objectives are to study the structure and the dynamic and thermodynamic properties of the synoptic and meso scale weather-producing disturbances in the Southeast and East Asian monsoon region, the South and East China Seas, and the western Pacific and the eastern Indian Ocean. The study focuses on the development and evolution mechanisms of these disturbances and their interactions with the different stages of the large-scale monsoons in the atmosphere and ocean, in particular the convective "Mei-yu" disturbances ("Changma" in Korea and "Baiu" in Japan) that developed following the onset and reinforcement of the southwest monsoon in the South China Sea. This work is supported by ONR Marine Meteorology.

APPROACH

Observational studies/Data analysis: Use archived gridded data from global NWP outputs and satellite data to determine the structure of meso and synoptic disturbances in various local regions. Use composite and principal component approaches to perform statistical analysis of the data.

Numerical modeling: Perform sensitivity and simulation studies of the observed monsoon disturbances with Navy's regional research and operational models. Models initialized with Navy and ECMWF global fields. The sensitivity studies look at both impacts of enhanced radiosonde data reports, the effects of topography and diabatic heating, and the satellite scatterometer data. The results are analyzed with vorticity and vertical motion diagnostic tools.

Field experiment: Participate in the international South China Sea Monsoon Experiment. The field phase with enhanced atmospheric and oceanographic observations over the South China Sea and its vicinity took place in May and June 1998. The field phase data, together with data collected from the concurrently held GEWEX Asian Monsoon Experiment, will be used both for the observational data

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analysis and the modeling studies, as well as to conduct validation for the models' analysis and parameterization schemes.

WORK COMPLETED

A combined diagnostic and numerical study of the vortex development in the Meiyu front during the 1992 East Asian summer monsoon onset. The vortex developed on the eastern side of the Tibetan Plateau and spun out heavily convective disturbances that moved eastward along the Meiyu front into the East China Sea. Potential vorticity inversion was used to diagnose the structure and intensification mechanisms of the vortex. The Navy's operational regional model was used to conduct numerical experiments on the effects of diabatic heating and terrain.

A numerical simulation of two summer monsoon cases occurring over Taiwan during heavy rainfall events in June 1997 using NORAPS. The heavy rainfall resulted from the development of mesoscale disturbances under enhanced low-level southwesterlies in the northern South China Sea. This work studied the processes that influenced the heavy rainfall development, and also evaluated the effect of including NSCAT surface winds, which were available during the events, on the numerical simulation and forecast.

Coordination of SCSMEX Field Experiment. Continued the national and international coordination and planning activities for the field phase of South China Sea Monsoon Experiment, and its coordination with the GEWEX Asian Monsoon Experiment, carried out in the summer of 1998.

RESULTS

Significant rainfall of the East Asian summer monsoon is produced by low-level disturbances that originated from mainly stationary vortices east of the Tibetan Plateau. Many previous studies found latent heating to be the dominant energy source for the development of these vortices during mature monsoon. This work uses the Navy's regional forecast model to study the development of a disturbance system during 15-17 May 1992, around the beginning of the monsoon season. The system was characterized by a preexisting stationary vortex in the Sichuan basin and the subsequent development of another vortex that propagated eastward along a pre-Meiyu front that moved into the Yangtze River valley.

The numerical simulation, in conjunction with an analysis of the ECMWF data using a potential vorticity inversion, indicates that during the first 24 h the stationary vortex was maintained by terrain effects. On 16 May, the forcings of an upper-level jet and a shortwave 500 hPa trough, along with latent heat release that may have been triggered by the upper forcings, intensified this vortex temporarily. Afterward, the vortex continued to develop by a low-level front-terrain interaction in which the frontal secondary circulation turned the basin-scale east-west overturning counterclockwise while the low-level vertical easterly shear was enhanced. This configuration tilted the vertical shear into a source of cyclonic vorticity. The upper-level forcings and the associated latent heat release also spun up the eastward propagating vortex, whose subsequent intensification was mainly the result of latent heat release along the front.

Sensitivity experiments indicate that forcing of the cold air southward by the terrain, and enhancement

of the secondary frontal circulation by condensation heating were required for the low-level front to move sufficiently southward into the Yangtze River region to produce the interactions for the development. If the front stayed in a more northerly position, the stationary disturbance would not be strengthened by the terrain-front interaction and even had the propagating disturbance developed, it would move eastward too fast to accumulate the moisture for heavy rainfall.

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Tropical numerical weather prediction suffers from lack of observations. Several authors have found some improvements from using the SEASAT and ERS-1 scatterometer winds. However, the improvements occur mainly in the southern hemisphere, and particularly in midlatitude large-scale weather systems for which the surface winds can effectively determine the surface pressure through geostrophic relationship and planetary boundary layer models. The 1996-97 NSCAT winds contain rich information on the surface mesoscale structure in the tropical coastal regions. This work studies the possibility of using this information for tropical, coastal mesoscale forecasting of severe weather. The chief problem is that single-level winds at the surface without space and time continuity are quickly overcome by the model dynamics. For tropical mesoscale systems, initializing the sea-level pressure from the surface wind is also more problematic because of the decreased validity of the geostrophic or gradient wind relationship.

In view of these difficulties, we design an experiment to test the possible impact of NSCAT data in the NWP of mesoscale heavy precipitation near terrain in a tropical monsoon setting. In such situation a difference in the low-level winds may lead to a significant difference in low-level convergence and vertical motion, whose effects may be amplified by moisture and the terrain effect. We select the two heaviest summer monsoon rainfall cases during the NSCAT period, 4-5 June 1997 and 13-14 June 1997, and use the NORAPS model to run the experiment. In both cases, rather small and localized areas of conspicuous differences between operational analysis and NSCAT winds are found. The differences are applied to modify the surface - 850 hPa analyses. The results, as verified by surface observations, showed significant improvement in the 24 h forecast of rainfall pattern and intensity. Another experiment setting the terrain over Taiwan to zero, but keeps the land surface characteristics, resulted in very little improvement of the rainfall forecast when NSCAT wind is introduced.

The improvement is attributable to a better simulated monsoon meso-low on the lee side of the stronger southwesterly winds in the northern South China Sea. The improvements were obtained because of the importance of the monsoon convection and terrain effects. Although the NSCAT winds produced only localized differences from the operational surface wind analysis, the lee side mesoscale low system in both cases were better simulated because the small differences are manifested by the effects of monsoon convection and terrain.

Participated in the SCSMEX Organizing Committee meeting and the science planning meetings in December 1997 and March 1998. Revised the science plan and the implementation plan for the field phase of SCSMEX. Coordinated radiosonde, ship and radar plans among U.S., Mainland China, Taiwan, Australia and ASEAN countries.

IMPACT

The research on the East Asian monsoon disturbances provided better understanding of these heavy weather systems during the onset and active stages of the monsoon. Numerical experiments using the

NSCAT data for the first time showing a positive impact of the satellite scatterometer derived surface winds in numerical simulation and forecasting of tropical mesoscale rainfall. These efforts lead to better design of future modeling efforts. Continuous interaction with NRL scientists on the application of Navy models provided user feedback to the modelers on the model performance and special characteristics for the South and East China Sea, Japan Sea, Yellow Sea, eastern China, Japan and Korea region.

RELATED PROJECTS

1. Joint work with NSF Project on East Asian Monsoon at NPS. The NSF project conducted observational and theoretical studies of the Asian monsoon motions and complements the numerical modeling efforts of this project.

2. Collaboration with the NASA Scatterometer Project at JPL, P.I. Dr. W. Tim Liu. The JPL project provided the NSCAT data, technical assistance and programming support for running the NSCAT numerical experiment.

PUBLICATIONS

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lIN-HOUSE/OUT-OF-HOUSE RATIOS

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